



GREEN RENEWABLE PRIVATE POWER PRODUCTION IN TANZANIA

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Industrial management

31.05.2011

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1. INTRODUCTION

Tanzania is the country located in eastern Africa, Geographic coordinates are 6° 00' S, 35° 00' E, the total area is 947,300 square kilometers. Population is about 42,746,620. Tanzania is one of the world's poorest economies in terms of per capita income, however, Tanzania average 7% GDP growth per year between 2000 and 2008 on strong gold production and tourism (in 2010 GDP purchasing power parity was \$ 62.22 billion). The economy depends heavily on agriculture, which accounts for more than one-fourth of GDP, provides 85% of exports, and employs about 60% of the work force. [2]



Figure 1 [1]

Electricity generation, transmission and distribution in Tanzania are through the Tanzania Electric Supply Company known as Tanesco. The company is 100% government owned and is responsible for 98% of the country's electricity supply. Petroleum, hydropower and coal are the major source of commercial energy in the country. The biomass energy resource, which comprises fuel-wood,

Charcoal from natural forest and plantations, accounts for 93% of the total energy consumption. [3]

The electricity sub sector contributes about 0.6 per cent of total energy consumption. Two thirds or 381 MW of Tanzania's installed capacity is hydro powered. It is reported that Tanzania has an estimated 3800 MW of economic hydro potential capacity. The Hydropower is prone to draught effects so some Thermal power stations have been installed. There are plans to connect with neighboring countries of Zambia and Uganda to the national grid to boost the supply of electricity [3]

Droughts over the East Africa region have had severe effects on the electrical power supply. Blackouts and power rationing as a result of low water levels in the hydro dams have forced Tanesco to rely on gas-powered generators and to look increasingly at thermal projects for future capacity increases. Because of the real situation in Tanzania as mentioned above the green renewable private power production is need as much as possible to boost the capacity of Tanesco to supply electricity in the country. The private sector has a guaranteed market for the power it has produced, its risk free market.

Green renewable private power production is system which involved three main processes, first wastes handling, second is biogas production and the third one is electricity power production. The final production obtained ready for to be transferred to the customer (Tanesco). This project is environment friendly directly and indirectly, this means by producing more electricity power it decrease the deforestation which is always catalyzed by lack of energy supply and also by proper handling of waste improves the air quality (from dangerous bacteria and bad smell) and prevent the society from related diseases.

2. OBJECTIVES

There are two main objectives of green renewable private power production which are

1. Possibilities of running this project in Tanzania, this includes the followings below.

.Technology

. Tanzania economy

.Market

.Rules and regulation

.security

.Infrastructure

.Labour force

2. Economic viability of the project in Tanzania, it includes the followings below.

.The costs of installing this technology

.The cost of running the project

.Profitability

.Rate of return

.Payback period

.Price comparison of electricity between hydro power production and the green renewable power production

3. LITERATURE REVIEW

3.1. BIO WASTE HANDLING

Bio waste is an organic waste that is putrescible which liable to decay or spoil. This can include food waste, some agricultural wastes and some sledges. There are two main sources of bio waste which municipal sources and industrial sources. [4]

1. Municipal bio waste

About 2/3 of the waste produced by homes and business comprises ‘organic’ or natural materials. These materials will break down over time (‘biodegrade’) by natural processes. This waste stream is termed Biodegradable Municipal Waste (BMW). BMW comprises paper and cardboard, food waste, textiles and wood. When landfilled, these materials degrade and generate leachate and landfill gas. BMW requires recycling or biotreatment in order to avoid these problems and to avoid dependence on landfill as a disposal option. [4]

2. Industrial bio waste

Industrial processes including wastewater treatment, food or drink preparation, agriculture, forestry and pharma chem industry are examples of processes that may produce large volumes of putrescible waste streams. These materials are often highly putrescible and may be very liquid in form. Therefore biotreatment is required to ensure that environmental protection can be assured. [4]

A. Composting

Composting is a cost effective and natural method for “recycling” waste organic materials into a fertiliser and soil conditioner for land. These organic waste streams can include the following categories

.Food organics waste

.Canteen / catering waste

.Fruit or vegetable waste

.Wood and timber

.Agricultural organics

.Bio solids / sludge

Composting systems

There are different forms of composting systems available to control or optimize compost production by manipulating temperature, oxygen and moisture during composting. These include:

Windrow systems.

This system of composting involves aeration of horizontally extended piles formed by a front-end loader or windrow turner

In-vessel composting systems; Are systems of composting involving use of an enclosed chamber or vessel in which (in most cases) the composting process is controlled by regulating the rate of mechanical aeration.

Benefits

It is a cost effective alternative for treating organic waste streams as it reduces the volume of organic waste going to landfills while providing a nutrient or engineering material for a variety of environmental purposes. [5]

B. Anaerobic digestion

An anaerobic Digestion (AD) is to treat bio wastes such as sewage sludge, organic farm wastes, municipal bio wastes and other industrial organic and food wastes. it treats organic materials in the absence of air/oxygen (anaerobic) in a reactor whereas composting works in the presence of air/oxygen (aerobic),it differ from composting.



Figure 2: [6]

Anaerobic digestion is also used for ‘wetter’ waste streams than composting. It has been used for over 150 years to create biogas from bio wastes.

The benefits of anaerobic digestion include:

- *It provides an alternative treatment process for Bio waste as opposed to disposing in landfill.

- * It can provide an effective means of recycling waste to produce biogas which can be converted to electricity in a Combined Heat & Power (CHP) plant and also produce a digestate which has fertilizing/compost qualities and a liquor which is normally an excellent organic fertiliser.

- *The advent of climate change policy and renewable energy policy in the form of proposed carbon taxes is making this technology more attractive to businesses that produce Bio waste. [6]

3.2. BIO GAS PLANT

The below figure illustrate in the simplest form the way green renewable power production works. The system involved three main processes, first municipal solid wastes handling, second is biogas production and the third one is electricity power production. The final production obtained ready for to be transferred to the customer.

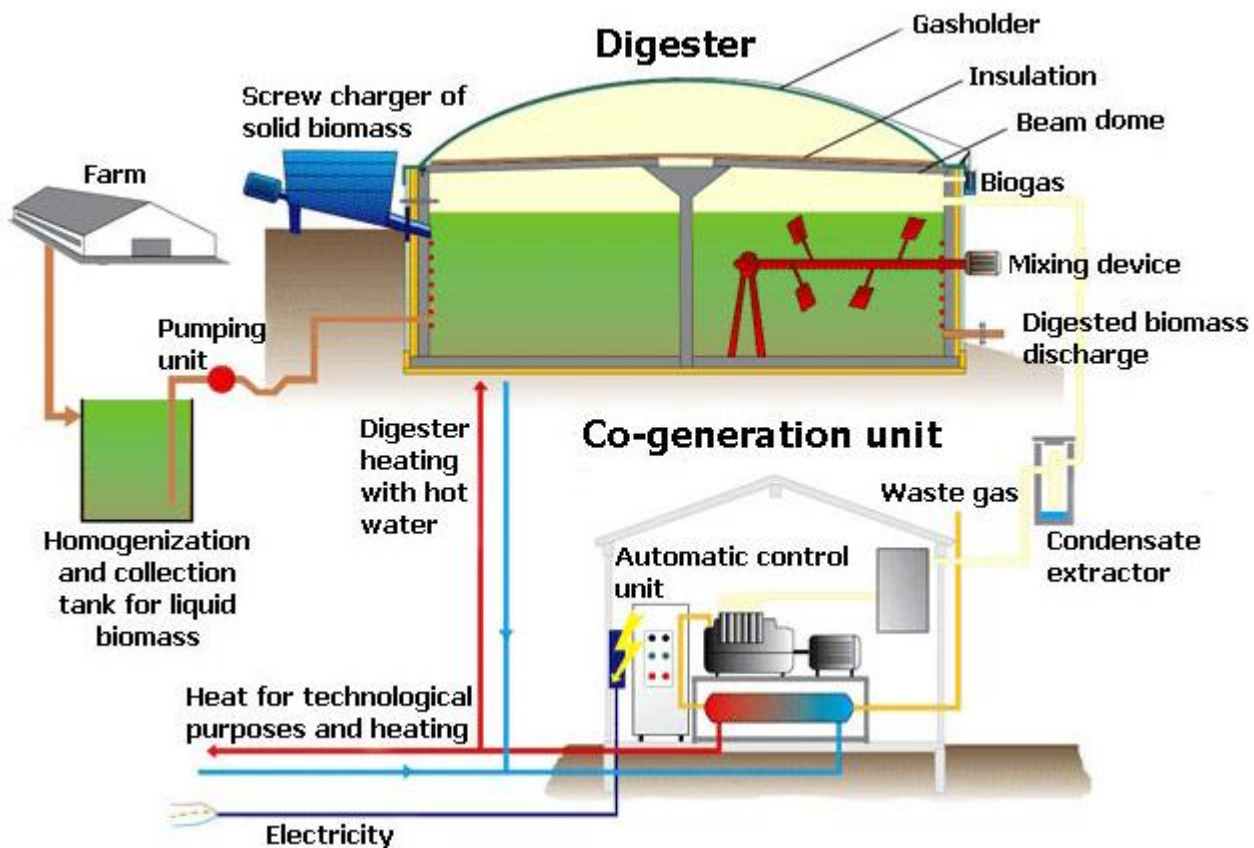


Figure3. [10]

COMPONENTS:

1. Digester

2. screw loader
3. Inclined mixer
4. sub mercible mixer
5. Gasholder
6. External gas holder
7. Heating station
8. Automation and control
9. Separator
10. Biogas flare
11. biogas treatment system
12. Co-generation units
13. Methane filling station(CNG)
14. Waste water treatment systems

3.2.1. DIGESTER

Digesters are composed of panels. These panels are made of steel with high quality glass enamel cover made using technology of high temperature sintering. Enamel cover is extremely chemically-proof, shock and corrosion resistant and has long operational lifetime period. Digester can be quickly installed and dismantled. Each detail is well considered. Stainless steel manholes, reinforced holes for mixing devices, access holes everything design specially for biogas application



Figure4. Biogas reactor made of steel with fused glass coating[11]

Advantages of glass fused to steel enamel digesters compared to concrete digesters

- *longer lifetime
- *construction during winter is possible
- *false work is not required
- *reduced construction period
- *can be purchased under leasing scheme like equipment [11]

3.2.2. SCREW LOADER

Corn silage or another solid substrate supplied directly to digester by means of screw dosing system. Dosing system is equipped with weight sensors and electric drive, which are integrated into biogas plant central control system.

Bunkers with big volume equipped with two or three turbo augers in that way all augers can work simultaneously and during the discharge they switched one by one. Initially augers are actuated slowly and then rotation frequency is increased step by step allowing power saving and drive smooth operation during 24 hours a day. Very strong structure with acid resistant cover made of alloy steel allows system units increased through output capacity and work under heavy loads.

System is characterized by increased efficiency due to application of special scraper equipped with adjustable knives. Special drive with reliable planetary gearbox guarantees stable operation under

maximum loads and turning moments. Hydraulic control of the discharge door secures turbo auger and transporter cleaning allowing reliable operation even in strong frost.



Figure5 .Screw loader and dozer of biomass [12]

3.2.3. INCLINED MIXER-AGILATOR[13]

Inclined agitators are specially designed to work in aggressive environment. Due to efficient mixing floating layer is not form, which allows easy biogas release to the surface, also substrate sedimentation is avoided. Agitator propellers are manufactured with the help of special tools that ensure millimeter angle accuracy blade after blade. Depending on application and rotation direction we apply highly efficient propellers that can work in pull-in or pull-out modes.

Electric motor-driven agitators are designed for work in the explosion hazard environments of EX Zone 1 or EX Zone 2. All components, including the sealing membrane (gastight) for agitator tube lead-through, are UV-resistant and flame resistant. The propeller agitator is fitted from the outside through the opening in the digester wall. Agitator is fixed in position and sealed in the digester wall using a sealing plate or sealing frame. The sealing membrane is used for sealing of the agitator shaft in respect to the sealing plate of the moving agitator shaft that allows to remove the agitator without removing propeller from the digester. Propeller agitator is supported by two top links or optionally by rack-and-pinion jack and can be set steplessly to any angle of inclination. Propeller is driven by means of electric motor with two-step spur gear via a drive shaft and shaft tube with intermediate bearings. Thrust forces are absorbed by two tapered roller bearings. Agitator shaft, propeller and sealing plate or sealing frame is made of stainless steel.

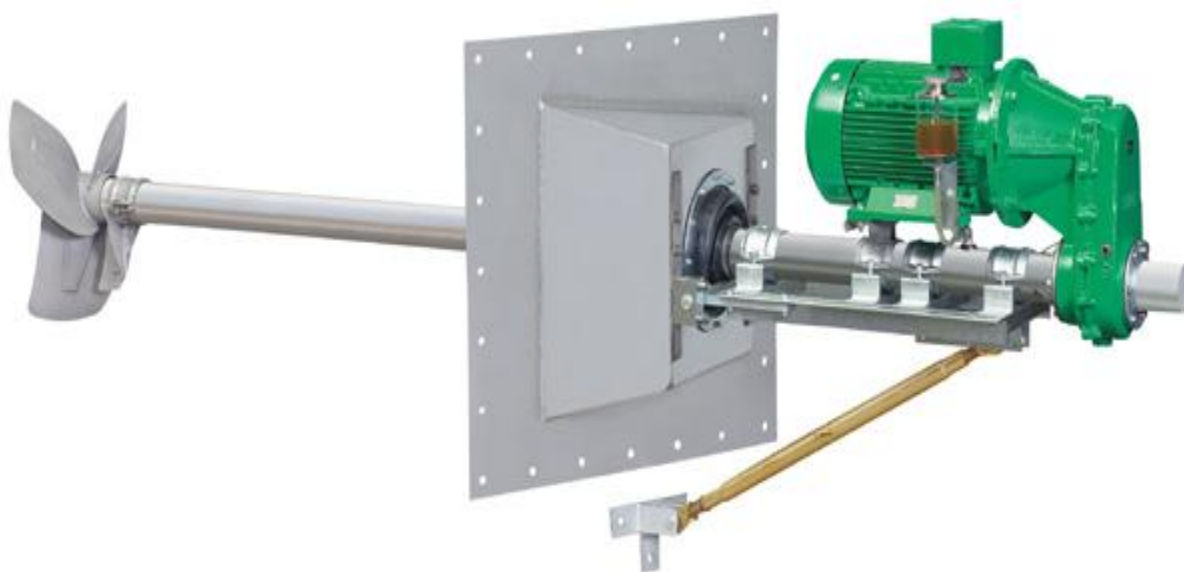


Figure6. Inclined agitator of biogas plant [13]

3.3.4. SUBMERSIBLE MIXER

The electric motor-driven agitator propeller is designed for submersion in the explosion hazard and explosive environments. Submersible agitator can be adjusted to most kinds of sliding masts by means of the motor support for height adjustment purposes. Due to 4-roller guidance of the motor support, the

agitator can be lifted and lowered without friction, even if the pull of the hauling cable is slightly angular. The geared motor is made of spheroidal graphite iron and painted, the propeller is galvanized and the motor support is made of stainless steel. Submersible motor agitator is designed as water pressure-tight monoblock unit for driving the three-vane propeller.



Figure7. Submercible agitator [14]

3.2.5. GAS HOLDER

Gasholder is a biogas storage it's mounted on the roof of reactor. Gas holder system has double layer structure. External cover dome is made of PVC and produced with special additives that are ultraviolet and precipitation resistant. Internal membrane, which is in direct contact with biogas, is made of special

material PELD. Internal membrane is stretched by pressure of produced biogas. Air is pumped between cover dome and internal membrane that makes pressure to upper side of membrane and give spherical shape to cover dome. Biogas pressure inside the gas holder in average is from 200 to 500 Pa.

Membranes are designed and cut at machines with numerical program control. Welding is made by high-frequency current welding. All of those give considerable advantages in terms of quality if to be compared with membranes that handmade and glued or welded by heating elements. The hermetic sealing in gas holder mounting system is secured by pilot-operated check valve. The pilot-operated check valve consists of profiled lock for mounting, pipes for membrane fixation inside the lock system, compressor to make pressure inside the pilot-operated check valve, drag bar, sealing tape and hermetic. For gas holder safe operation excessive pressure valve is installed. Acrylic inspection holes are included into scope of gas holder supply. Gas holder volume is enough for several operational hours. Gas supply systems include fan, condensate drainage system, desulphurization system etc.[15]



Figure8. Gas older for biogas [15]

3.2.6. EXTERNAL GAS HOLDER

Gas holder material (special PVC) is high voltage and open fire arson resistant, resistant to damages by sharp steel bar even red-hot. Gas holder is installed in special ventilated hangar. Gas holder designed to accumulate and store biogas under pressure 0,005-0,01 bar. Biogas supply to gas holder is done by means of special pipeline made of HDPE DIN 150. Gas holder equipped with safety valve in order to avoid overflow.



Figure9. Gas holder in special hangar [15]

Table 1: Technical characteristics of Gas holder

Parameter	Parameter
Height, m	6 - 10
Diameter, m volume, m ³	4 - 9
Operational volume, m ³	200 - 1000
Nominal gas pressure, mbar	10

3.2.7. HEATING SOLUTION

Fixed temperature is constantly supported inside the digester in order to maintain bacteria living conditions. Temperature inside the digester is mesophilic, which is about 37°C. Digester heating is made by means of heat agent. Inlet water temperature to digester heating system is 60°C. The outlet water temperature is 40°C. Heating system is a network of pipes placed inside the digester walls or to inner wall surface. In case biogas plant is equipped with co-generator the hot water for digester heating is supplied from engine cooling system.

Boilers fueled by biogas, natural gas or their mixture can be also used as heat power source for biogas plant. Boilers are located in biogas plant technical building. Digesters heating system is built in to digesters' bottom and on inside side digesters' walls. System consists of circulation pumps, pressure and temperature sensors, stop valves, membrane surge tanks. Heating system is constantly fed with polypropylene glycol solution. Heat supply networks are made of PVC pipes with heat insulation cover and laid in trenches.[16]



Figure10. Heating unit of biogas plant [16]

3.2.8. AUTOMATION AND CONTROL

Automation and control system is based on industrial sequence controller Siemens CPU315-DP2 and application of distributed peripheral system Sematic ET200S with operator's touch screen control panel OP277 Touch. Together with sensors and actuation mechanisms automation system secures automatic process control and biogas plant technological processes protection and regulation. Interaction between units is performed by means of PROFIBUS and MPI networks using RS-485 physical interface. Master program is developed with the application of Sematic Step7 development system and recorded to memory stick.

Automatics perform following:

*Constant level control by hydrostatic and emergency electric sensors;

- *Control over substrate loading and discharge from tanks with the help of weight sensors, flow meters, level sensors and substrate excess pressure relay
- *Substrate mixing regulation with the help of controller
- *Pressure control in heating system with the help of system recharge valve
- *Temperature control inside digesters
- *Gas quality control at gas analyzing system
- *Gas pressure control with the help of gas pressure sensor, cover dome level sensor, and safety valve
- *Quantity of produced gas with the help of gas flow meter. [17]



Visualization



Automatics

Figure11. [17]

3.2.9. SEPARATOR

Screw separator is used for separation of digested biomass into solid and liquid fractions. Separator is filled with the substrate from storage tank by gravity. Loading chamber equipped with oscillation unit that performs primary separation of liquid and solids by means of vibration, which significantly increases separation efficiency, especially for solid materials. Screw blades push the separated material to exit of the separator. Screen chamber is design in such way that corks of material are avoided. Pressure in primary part of the screen is not high but when solids concentration is increased and up to exit of solid fraction pressure significantly increased. Friction of solids in cylindrical nozzle and double valve of exit regulator make resistance at separator exit, which performs pressing. The material pressing level can be adjusted by the number and position of counterbalances. [18]

Solids concentration in separated substrate can reach from 25% up to 30% and this parameter can be adjusted. Screw separators can be equipped with electric drives and reduction gear ranging from 4kW to 11kW. Thanks to level switches completely automatic operation of separator is possible that does not require any control. Separator has integrated system of self-cleaning and does not require water for washing. When substrate is not supplied separator is switched off automatically. All parts of the separator those are in contact with the substrate are made of stainless steel. Screen chamber needs cleaning only once in 3-4 months, complete procedure takes not more than 30 minutes. [18]



Figure12. Separator [18]

3.2.10. BIO GAS FLARE

Biogas flares have the task of temporary or periodic burning of biogas produced by biogas plants or landfills in case there is no possibility to use it for energy production. Biogas flare is composed of a

flare burner and a flare substructure. It is designed according to the principle of an injection burner and consists of a nozzle, an injector with an air flow regulation, a flame protection tube, a fitting group and a flare control system. The gas flare is totally made out of stainless steel, whereas gas contacting parts are done in stainless steel.

The flare burner is made up of the flame protection tube, the injector and its supporting structure, the ignition and the flame monitoring. The flame protection tube and the injector are made out of stainless steel. The flare substructure bears the flare burner and takes up the vertically installed fitting group. On demand it is able to provide it with a sheet-metal covering for protecting the fittings from the weather. Then a door enables a good accessibility. The fitting group consists of a magnetic or motor-driven valve (slow opening, fast closing, de-energized closed), a flame arrester and two pressure switches. The flare control system is fitted in a control cabinet out of stainless steel that is mounted on the flare substructure.

Surplus gas is able to be burnt off by the flare once an adequate signal sets the flare into operation. Normally this signal is provided by the filling level indication of the gas holder or gas supply system.

The control cabinet contains the whole control system for the flame monitoring and the ignition of the flare. An ignition transformer feeds the ignition electrode that directly ignites the exhausting gas/air mixture at the injector. The combustion is monitored by an ionization electrode that controls the ionization current produced by the flame. If this ionization current breaks down at a failure of the flame, it will be detected by the ionization electrode and a re-ignition will be initiated by the automatic firing device. In case of a long running failure of the flame the gas supply will be interrupted and a malfunction message will be displayed. [19]



Figure13. Biogas flares [19]

3.2.11. BIOGAS TREATMENT SYSTEM

Biogas treatment system allows purify biogas up to bio-methane condition (complete analog of natural gas with methane concentration in the range of 90-97%). After treatment biogas can be used as vehicle fuel or to be fed in to the general natural gas grid.

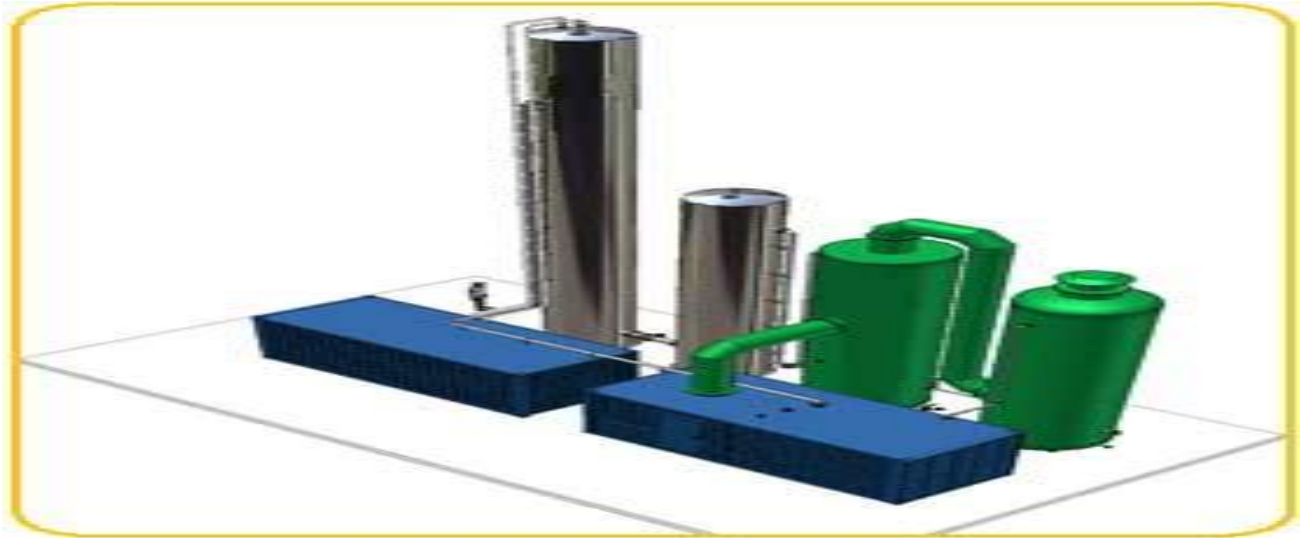


Figure13. 3D model of biogas treatment unit 250 m³/h capacity [20]



Figure14. Biogas treatment unit 500 m³/h capacity [20]

Description

One of the most efficient systems of anaerobic digestion biogas treatment is regeneration system. The working principle for that system includes two technological processes CO_2 , H_2S and moisture removal. Inlet biogas is initially compressed to operational pressure 8-10 bar. Then biogas directed to purification column and purified with cooled water under pressure. Water is supplied from cooling system from the top of the column in the reverse direction to the biogas flow. In that way CO_2 and H_2S admixtures are removed in purification column thanks to their solubility in water if to be compared to methane. Column is filled with special material in order to secure good throughput capacity and heat conductivity. [20]

The purification process is most efficient when water has low and constant temperature. For that purpose cooling system is included into the technological process. Water that is used for biogas purification contains dissolved methane and other gases that is why it is compressed to 2 bars and directed to methane regeneration column. Gas is extracted from the water and supplied to the inlet of the treatment system for purification and recirculation. [20]

Methane losses can be controlled by adjustment of pressure in the regeneration column. Methane regeneration from the water is performed in 3 ways:

1. Recuperated gas saturated with CO_2 , H_2S and CH_4 is directed to big purification circle with second compression at inlet compressor.
2. Gas extracted from the bottom of the column also directed to initial compression stage.
3. Recalculated water is directed to gas separation column for CO_2 and H_2S removal by air. Air and water form gas separation column is directed to bio filtration column which is filled with plastic balls that are used as bacteria carrier. As a result of intensive mixing bacteria removes remnants of H_2S and CO_2 . Microorganism removed from the balls come out as sludge. [20]

Gas drying system is installed after the purification columns which consist of a drying module, carbon filter. This system removes water remnants from a purified gas. Drying unit is self-cleaning and completely controlled by electronic system. For optimum process control levels of CO_2 , CH_4 , H_2O , H_2S and Wobbe-index are constantly fixed by electronic system, the results are displayed at system monitor.

The advantage of this system is low cost for biogas treatment due to usage of water as a main purification element.

Scheme of biogas treatment system

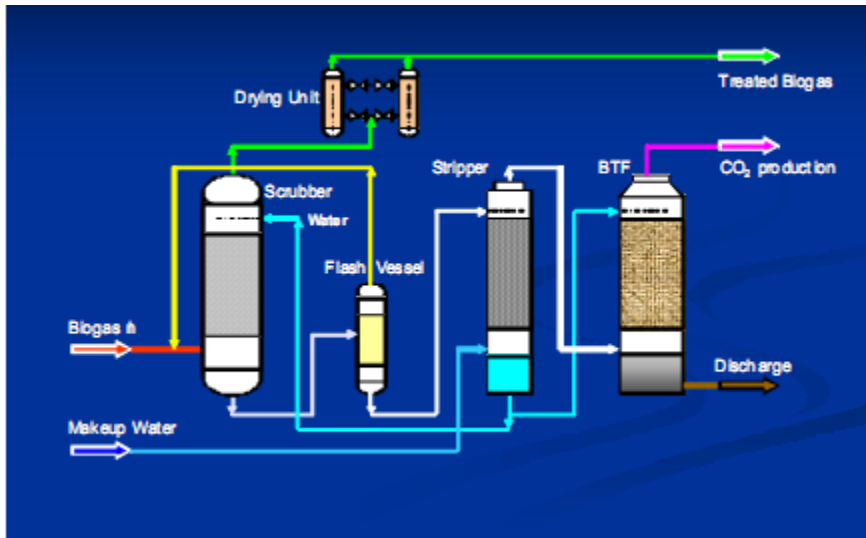


Figure14. Scheme of biogas treatment system

3.2.12. CO GENERATION UNITS

Co-generation heat power units (CHP) are the modules for combined production of heat and electrical power. Heat from conventional generation units is not utilized and released to environment. The co-generation unit uses this heat for heating purposes. Considerable gas saving is achieved. [21]



Figure15. Biogas co-generation heat power unit [21]

CHP are characterized by:

- *Low operational costs
- *High efficiency rate that in average is 85-90 %
- *Wide assortment of equipment
- *Perfect parameters for capacity switch (from 100% to 75% and 50% capacity) and good working characteristics
- *Process automatic control
- *60000 operational hours between overhauls
- *Easy installation and operation
- *Correspond to international standards for toxic exhaust gases emission
- *Avoids pollution of environment that is co-generation is the most ecology friendly energy production method. [21]

CHP plants work based on internal combustion engine fueled by biogas which moves the generator. Engine designed to run on biogas and its peculiarities are two systems for gas mixing with air and exhaust gases removal [21]

Main parts of CHP unit are:

1. Internal combustion engine;
2. Engine support frame;
3. Alternator (voltage 400 V, frequency 50 Hz);
4. Electricity distribution cabinet that can be equipped with stabilizer to avoid voltage jumps;
5. Engine cooling system with heat exchanger;
6. Container with noise insulation;
7. Container ventilation system

3.2.13. METHANE FILLING STATION

Gas filling station can be easily deployed in small area for filling of vehicles, buses and other technics. Filling station can be placed near roads and main traffic artery as well as in the territory of the company by using compressors with lower efficiency. [22]



Figure16 Gas filling station [22]

The working principle of gas filling station is based on complicated technology of gas preparation.

Initially station is plugged to gas and electricity line. As a gas source gas grid, biogas treatment system or accumulation blocks (virtual gas line system) are used. The accumulation blocks can be easily transported to their filling place as they are of modular execution.



Figure17. Gas accumulation module [22]



Figure18. Dispenser

Gas is supplied from the source and can be initially dried or purified from admixtures. After that gas is compressed to operational pressure and supplied to accumulation block where constant gas volume is

supported. From the accumulation block gas is filled into the vehicles tanks and is ready to be used as fuel. In case of heavy vehicles traffic gas can be supplied directly from the compressor. Filling station is deployed to the concrete base.

In case filling station is made in container module, capital structures are not required, only concrete ground should be prepared. Water for technological purposes is not required, compressor has air cooling.

Gas filling station works in automatic mode. Automatics system provides all station parameters control, station switch on and off in case of any emergency. Station monitoring system allows control the station via GSM channel by transmitting current operational information and problems. Station equipment is made in explosion proof execution. Gas filling station also equipped with safety system consisting of gas control, fire emergency and automatic fire fight module.

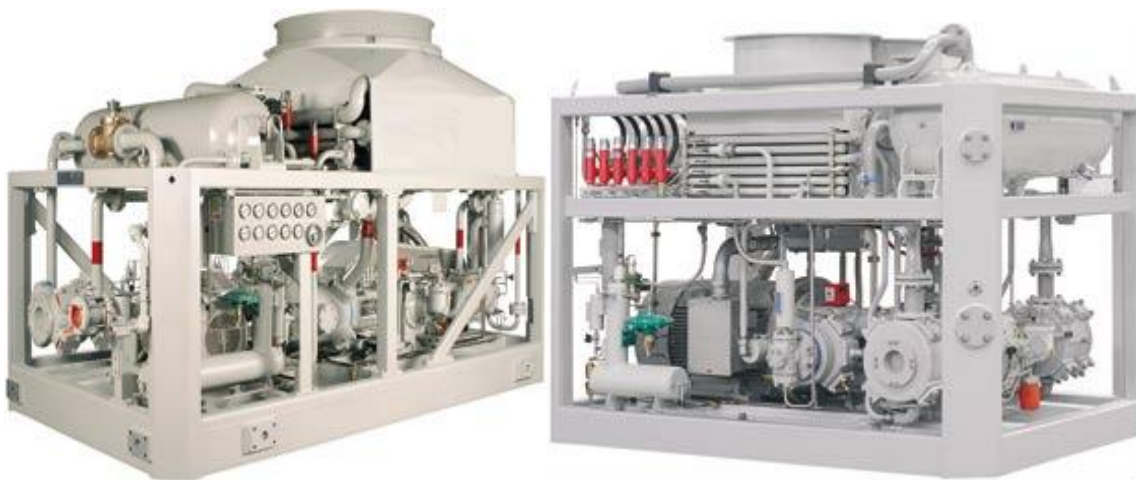


Figure19. Compressor station [22]

As customers request filling station can be equipped with remote control of control panel. Optionally compression unit and all systems can be executed in container for outdoor usage with heating; container is explosion and noise proof. [22]

3.2.14. WASTE WATER TREATMENT SYSTEMS.

High level of purification allows achieve all the requirements for open water surfaces and ground waters protection. This system is especially efficient when is used in combination with micro and ultra-filtration stages.

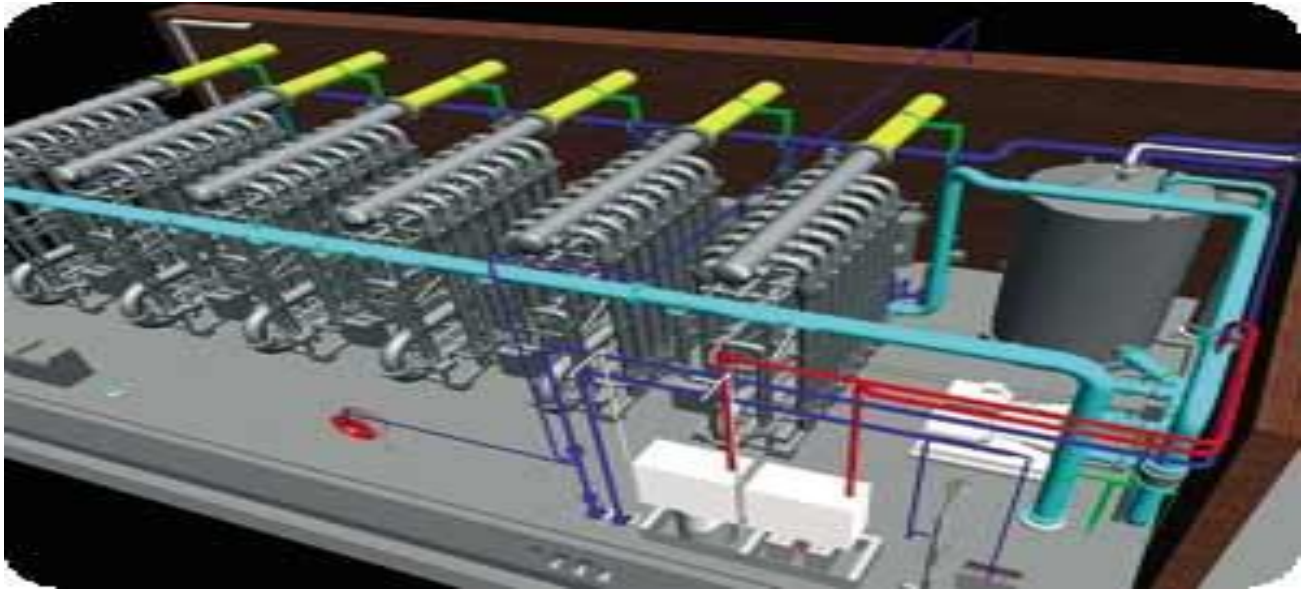


Figure20. 3D model of membrane treatment unit [23]

Main peculiarity of membrane bioreactor (MBR) from conventional air tank treatment system is presence of membrane module which is used for detachment of sludge and is perfect alternative for sludge sedimentation in secondary sedimentation tanks. Membrane module consists of 10-20 membrane cartridges. Each cartridge has from 5 to 10 membrane fiber bunches. Empty fiber membrane is string with outer diameter about 2 mm and up to 2 m length. The string surface is an ultra-filtration membrane with pore dimension 0,03 – 0,1 micro meter. Each bunch consists of 100-1000 membrane fibers and equipped with pipe for filtrate discharge. The pore dimension is physical barrier sludge microorganisms penetration as their dimension is more then 0,5 micro meter. Thanks to that it is possible to detach activated sludge from water and decrease concentration of suspended solids in treated water to the value of 1 mg/l and even less. Filtration is performed with the help of vacuum that is made on internal membrane fiber surface by self-priming filtration pump. At that mixture of waste water and activated sludge is filtrated by membrane surface from outer to inner surface. Purified water

is directed by flow pipe to disinfection unit and activated sludge is constantly kept in suspended state by aeration system of membrane module.

Technology peculiarities

1. Refusal from gravity sludge detachment system allows make activated sludge concentration in bio reactor 10-20 g/l (conventional air tank value up to 3 g/l).
2. Hi concentration of activated sludge makes possible bioreactor operation in low loading mode that makes reserve for oxidation ability, increases biocoenosis stability. In comparison to gravity method changes in biocoenosis of activated sludge can be traced. Sludge age in MBR makes 25-30 days and sometimes increases 60-70 days. At that main part of activated sludge is represented by low growing micro flora, which is most efficient for decomposition of hardly oxidation organic substances in waste water. Low growing micro flora predomination allows considerable reduction of activated sludge increase and as a result decreases capacity of sludge dewatering equipment.



Figure21. Membrane module in operation [23]

3. Allows following results for waste water treatment efficiency:

*BOD: more than 98%

*COD: 85-95%

*Suspended solids: less than 1 mg/l

*Ammonia nitrogen: more than 98%

*Heavy metals removal: 25-80%

*Bacteria removal: more than 99,999%

*Viruses removal: more than 99,9%.

4. Activated sludge flakes dimensions 5-10 times less than in other aeration systems. Such activated sludge dispersity leads to wider contact area of microorganisms and waste water. As a result the inert substances, heavy metals, micro waste adsorption efficiency increases.

5. Due to small dimension of membrane pore that is smaller than bacteria and virus cell, partial disinfection in MBR is performed. Bacteria removal efficiency 99,999%, viruses removal efficiency 99,9%. Waste water treated in MBR can be reused for non-potable purposes.

6. High sludge concentration can decrease retention time of waste water in treatment facility. As a result the area for treatment plant 2-4 times less than conventional systems require.

7. As an option MBR can be produced in container

3.3. Electric power production

Molten Carbonate Fuel Cells (MCFC)[8]

Molten Carbonate Fuel Cells (MCFC) are in the class of high-temperature fuel cells. The higher operating temperature allows them to use natural gas directly without the need for a fuel processor and have also been used with low-Btu fuel gas from industrial processes and other sources and fuels. Developed in the mid 1960s, improvements have been made in fabrication methods, performance and endurance.

MCFCs work quite differently from other fuel cells. These cells use an electrolyte composed of a molten mixture of carbonate salts. Two mixtures are currently used: lithium carbonate and potassium carbonate, or lithium carbonate and sodium carbonate. To melt the carbonate salts and achieve high ion mobility through the electrolyte, MCFCs operate at high temperatures (650°C).

When heated to a temperature of around 650°C, these salts melt and become conductive to carbonate ions (CO_3^{2-}). These ions flow from the cathode to the anode where they combine with hydrogen to give

water, carbon dioxide and electrons. These electrons are routed through an external circuit back to the cathode, generating electricity and by-product heat.

Anode Reaction: $\text{CO}_3^{2-} + \text{H}_2 \Rightarrow \text{H}_2\text{O} + \text{CO}_2 + 2\text{e}^-$

Cathode Reaction: $\text{CO}_2 + 1/2\text{O}_2 + 2\text{e}^- \Rightarrow \text{CO}_3^{2-}$

Overall Cell Reaction: $\text{H}_2(\text{g}) + 1/2\text{O}_2(\text{g}) + \text{CO}_2 (\text{cathode}) \Rightarrow \text{H}_2\text{O}(\text{g}) + \text{CO}_2 (\text{anode})$

The higher operating temperature of MCFCs has both advantages and disadvantages compared to the lower temperature PAFC and PEFC. At the higher operating temperature, fuel reforming of natural gas can occur internally, eliminating the need for an external fuel processor. Additional advantages include the ability to use standard materials for construction, such as stainless steel sheet, and allow use of nickel-based catalysts on the electrodes. The by-product heat from an MCFC can be used to generate high-pressure steam that can be used in many industrial and commercial applications.

The high temperatures and the electrolyte chemistry also have disadvantages. The high temperature requires significant time to reach operating conditions and responds slowly to changing power demands. These characteristics make MCFCs more suitable for constant power applications. The carbonate electrolyte can also cause electrode corrosion problems. Furthermore, since CO_2 is consumed at the anode and transferred to the cathode, introduction of CO_2 and its control in air stream becomes an issue for achieving optimum performance that is not present in any other fuel cell.[8]

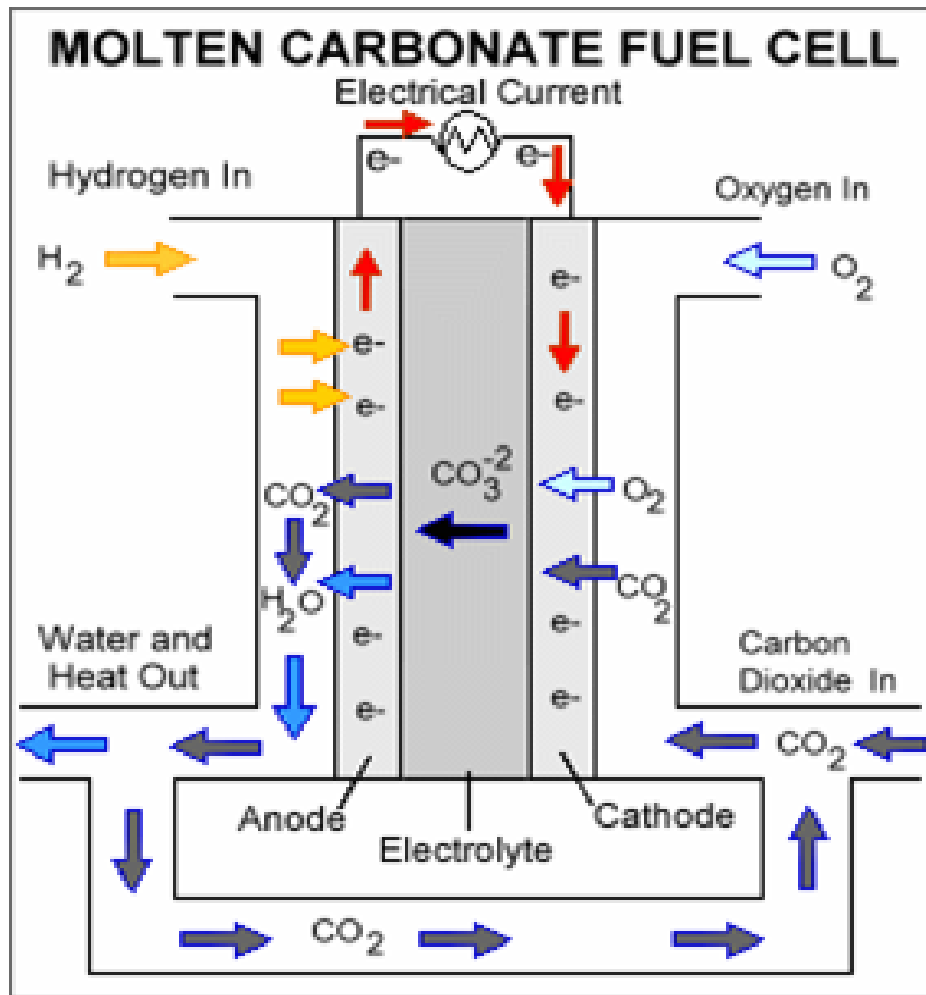


Figure22. Molten Carbonate Fuel Cells [9]

3.4. ECONOMIC THEORIES

3.4.1. Payback period

Payback Period is a financial metric that answer the question: How long does it take for an investment to pay for itself? Or, how long does it take for incoming returns to cover costs? Or, put still another way: How long does it take for the investment to break even. [24]

Evaluation of the Payback Period Method:

The payback method is not a true measure of the profitability of an investment. Rather, it simply tells the manager how many years will be required to recover the original investment. Unfortunately, a shorter payback period does not always mean that one investment is more desirable than another.[25]

Another criticism of payback method is that it does not consider the time value of money. A cash inflow to be received several years in the future is weighed equally with a cash inflow to be received right now

Formula:

Payback period = Investment required / Net annual cash inflow

Note.

If new equipment is replacing old equipment, this becomes incremental net annual cash inflow

3.4.2. Internal Rate of Return (IRR)

The internal rate of return (IRR) is the rate of return promised by an investment project over its useful life. It is some time referred to simply as yield on project. The internal rate of return is computed by finding the discount rate that equates the present value of a project's cash out flow with the present value of its cash inflow In other words, the internal rate of return is that discount rate that will cause the net present value of a project to be equal to zero. [27]

Formula:

[Factor of internal rate of return = Investment required / Net annual cash inflow]

3.4.3. Net Present Value (NPV)

Under the net present value method, the present value of a project's cash inflows is compared to the present value of the project's cash outflows. The difference between the present values of these cash flows is called "the net present value". This net present value determines whether or not the project is an acceptable investment.[27]

Table 2: Determination of the effect of net present value

If the net present value is	Then the project is
positive	Acceptable since it promises a return greater than the required rate of return
zero	Acceptable, since it promises a return equal to the required rate of return.
Negative	Not acceptable, since it promises a return less than the required rate of return

Net Present Value Method - Comparing Competing Investment Projects [28]

The net present value method can be used to compare competing investment projects in two ways. One is the total cost approach, and the other is the incremental cost approach

Total Cost Approach:

The total cost approach is the most flexible method for comparing competing investment projects

Incremental Cost Approach:

When only two alternatives are being considered, the incremental cost approach offers a simpler and more direct route to decision. Unlike the total cost approach, it focuses only on differential costs.

Technically, the incremental cost approach is misnamed, since it focuses on differential costs (that is, on both cost increases and cost decreases) rather than on just on incremental costs. As used here, the term incremental costs should be interpreted broadly to include both increases and cost decreases.

The procedure is to include in the discounted cash flow analysis only those costs and revenues that differ between the two alternatives being considered

3.5. LAWS AND GUIDELINES CONCERNING THE BIO GAS PLANT AND ELECTRICITY PRODUCTION IN TANZANIA[30]

3.5.1. Construction of plants

Biogas plants are considered as commercial plants, which are located in industrial zones. The location of a biogas plant outside an industrial area is legal if it does not conflict with public interest. This is not the case, when

.It serves an agricultural enterprise whose ground is mostly used for other purposes.

.It is installed away from settlements. This is desired because of its demand on agricultural products, its requirement to remove the residue.

.It cannot cause environmental damage and is not affected by natural climate influences.

.It serves the public supply of electricity, gas, heat and water.

.It does not interfere with land use planning, the landscape plan or any other plan, especially for the utilization of water and the avoidance of emissions.

.No uneconomic costs are incurred for the infrastructure for the supply and the waste removal of the plant or for security and health procurement.

.It does not interfere with existing areas whose soil, monuments, and relaxation value are environmentally protected.

.It does not conflict with existing measures to improve the agricultural structure or the water situation.

3.5.2. Risk of explosion

The companies have to avoid the risk of explosion by following the guidelines for explosion prevention, the regulations concerning electrical systems in spaces where there is a high risk of explosion, the technical regulations concerning flammable liquids and the advices contained in these regulations, and the regulations of the employer's liability Insurance Association

3.5.3. Risk of fire

The fire risk can be reduced in the plant by dividing the plant into fire protection sectors e.g. the bioreactor and gasholder, the gas consumption equipment, and the gas compressor. Certain distances must be maintained between the fire protection sectors. Depending upon how much space is available in between the material of the external walls of buildings containing equipment.

The protection distances around aboveground fixed gasholders:

The protection distance can be smaller if endangered spaces are covered with earth or a suitable metal guard or fire protection insulation is installed. Consider table

Table 3: Metal guards sizes

Gas volume per tank meter cubic	<300	300 to 1500	1500 to 5000	5000<	Material of the walls
Fire break in m	6	10	15	20	Any material class B
Fire break in m	3	6	10	15	Noncombustible
Fire break in m	3	3	6	10	class A, fire

The protection distances around underground and earth-covered gasholders:

For such gasholders the following protection distances are to be provided around armatures and openings. Consider a table below

Table 4: Fire breaks (underground gasholders etc.)

Gas volume per tank meter cubic	<300	300 to 1500	1500 to 5000	5000<
Fire break in m	3	6	10	15

Table 5: Fire breaks (balloon gasholders etc.)

Gas volume per tank meter cubic	<300	300 to 1500	1500 to 5000	5000<
Fire break in m	4.5	10	15	20

Fire protection measures

Measures relating to the design

- A. The prescribed protection distances must be realized, the fire protection zones must be free of buildings and the metal guards must be correctly dimensioned.
- B. All openings in fire walls must be provided with fire resistant and self-closing covers. All doors in the fire walls must at least be fire retardant and self - closing and/or lockable, if they don't lead into the open air.
- C. No gases can settle at any place in the factory
- D. Gas pipes in all areas must be insulated to give protection against continuous fire and provided with fire protection flaps.
- E. Gas holders from flammable materials in fire-protected areas must be shielded against radiation. The shield should be made of non-flammable materials.
- F. The escape doors must open to the outside.
- G. The certified flame traps must be installed as safety devices in all pipes to and from the gasholder close to the consumer according to the prescriptions of the manufacturer. The flame traps must be easily cleaned and correspond to the standards.
- H. There must be adequate and well-marked routes for fire brigade vehicles. All the roads were constructed such that they can be safely used by fire brigade vehicle and the routes must always be free.
- I. There must be enough fire extinguishers on plant site; at least 12 portable units of suitable extinguishing agent should be available per plant or per fire protection sector.
- J. A minimum of one portable fire extinguisher available at the gas consumption equipment building, easily seen, easy to reach in case of fire, and always working.
- K. There must be hydrants available which are capable of delivering 1600 L min – 1 water for a period of 2 hours.
- L. All areas must be clearly marked showing their use

Measures relating to organization

- A. Smoking, naked flames and storing of flammable materials must be forbidden in the entire area of the plant.
- B. The fire protection posts set up and suitable fire extinguishers must be made available, when work involving a risk of fire is carried out such as welding, abrasive cutting, soldering, etc. And a use of a naked flame
- C. All hazardous areas and safety areas must be marked example the entrances to gasholders.
- D. There must be a responsible person designated for all fire protection measures and fire protection exercises must be carried out regularly.
- E. The local fire brigade must be informed about the entire plant in detail and a fire brigade plan must be available in accordance with local regulate.

3.5.4. Harmful exhaust gases

Germ

The microorganisms take part in the fermentation process. There are no special protection devices necessary. But substrates and also residues often contain organisms which do not participate in the process, like viruses and parasites, which can have severe effects on the health of humans as well as on the environment.

Table 6: Infectious agents for humans

Infectious agent	Class of risk	Sources	Uptake and illnesses provoked
Escherichia coli	2	Stomach - intestine bacterium, which is excreted.	Oral uptake .A possible reason for stomach - intestinal illnesses, diarrhea
Klebsiella pneumoniae	2	In the stomach - intestine tract, soil, water, cereals	Oral uptake .Only with low immunity are urinary passage and airway problems caused
Swine fever	2	In meat of pigs, even in cured and frosted meat.	Sputum, secretion of the eyes, breathes. Fever, cramps, palsy, bleeding, cardio - vascular disease
Protozoans	2	Waste water, sewage sludge	Oral uptake epidemic (malaria, sleeping sickness, amebiasis)
Picornavirus	2	In saliva, nasal	Transfer through

		discharge, sperms, and milk of infected animals	contact with animals, persons, vehicles via the air, Virus of aftosa. The virus is inactivated by temperatures above 56 ° C or acids
Erysipelothrix rhusiopathiae	3	Pigs, poultry, crustaceans, and fishes	Via injuries to the skin in contact with infectious material. redness
Brucella	3	Cows, sheep, goats, pigs, dogs	Injuries of the skin and mucosa through dust expulsion from infected animals into the air. Bacteria containing milk and milk products Brucellosis, Malta fever

Table 7: Limits for substances in exhaust air according local regulations

Average value	Over one day	Over half an hour	Over one month	Of a sample	Over the time of sampling
Dust	10 mg m ⁻³	30 mg m ⁻³			
Organic matter (TOC)	20 mg m ⁻³	40 mg m ⁻³	55 g Mg ⁻¹		
Nitrous oxide			100 g Mg ⁻¹		
Odors				500 GE m ⁻³	
Dioxins/furans					0.1 ng m ⁻³

Table 8: Limits for ammonia and organic matter

Parameter	Discharge rate [kg/h]	Average value over one day [mg/Nm³]
Ammonia	≤ 0.15	≤ 30
Organic matter as carbon	≤ 0.50	≤ 50

Measures relating to the organization

- A. All necessary personal hygiene measures given in local regulations must be considered, mainly from the Tanzania employer's Liability Insurance Association.
- B. The operators have to be instructed, on the basis of written instructions, to wear protective clothing such as work clothes for skin protection, gloves to protect against mechanical injury and against chemicals and microorganisms, safety shoes, eye protection against splashing, and respiratory protection against airborne germs.
- C. The operators have to be inoculated, in accordance with the recommendations of the national insurance corporation of Tanzania limited (NIC).
- D. The cleaning work have to be carried out from safe locations and from the downwind side, this includes dirty implements and vehicle cabs properly cleaned. And rats and other vermin effectively have to be controlled and eliminated as well.
- E. Weather conditions have to be considered when work is planned

Measures relating to control

- A. Frequently checkup is a must, to determine whether the regulation is met which germ reduction is.
- B. Gas detectors with test tubes must be installed for the evaluation of health dangers. (In these detectors, gas is pumped through a test medium.)
- C. There must be a written procedures for pest control, cleaning, hygiene control, and Sampling at the necessary time intervals, and is the necessary equipment provided

3.5.5. Noise protection

Noise is defined to be disturbing sound. Any location where sound does not cause disturbance, even it is very loud, does not incur restrictions. Transportation of the co-ferments, pumps, compressors, and emergency cooling systems also causes noise.

Table 9: Limits for noise according to local regulations

Time	Housing area	Housing and commercial area	Commercial area	Industrial area
Day 06:00 – 22:00	50 dB(A)	60 dB(A)	65 dB(A)	70 dB(A)
Night 22:00 – 06:00	35 dB(A)	45 dB(A)	50 dB(A)	70 dB(A)

Noise protection measures

- A. All workers and operators must wear ear protection correctly.
- B. All pipes and piping break through must be insulated against noise.
- C. The plant must be located well away from settlements, its better in the industrial area, to avoid disturbing civilians by the noise produced by the plant.

3.5.6. **Prevention of injuries**

This involves some risks of injuries which are avoidable.

Measures relating to design

A. Controlled work.

B. All components must be sufficiently illuminated.

C. The machine safety regulations have to be applied. The TBS (Tanzania Bureau of Standards) sign has to be marked on all machinery together with a declaration of conformity.

D. Precautions have to be taken to prevent falls during operational, regularly maintenance and

Measures relating to organization

A. The operating instructions for all machines must be provided and all operators have to be adequately instructed

B. Instructions must be given concerning operation, monitoring, behavior in special situations such as damage and disturbances, required tests, responsibilities, and authorization for access to the electrical installations.

C. All electrical devices have to be validated by an expert.

4. FEASIBILITY STUDY

4.1. Location of the plant

In this part one has to choose the best location for the plant to be built, the best location must be logistically convenient. It must be easy for the raw materials to reach the plant from the suppliers and at low cost. It must be qualified to the conditions of National Environment Management Council (NEMC) concerning the location of industrial plant. It also must be easy to reach our customers grid (Tanesco)

The city of Dar es Salaam is good target due to availability raw materials at large quantity and good quality. **Vikindu** is an industrial area outside the city, it's about 22km from the Dar es Salaam city center. This is the perfect location for the construction of the biogas plant if National Environment Management Council (NEMC) will approve the place, roads are in good condition, availability of water and it's far from civilians home. It cost about TZS 20,000 (€9,295.63) for 0.1 hectares .But for this kind of project which raw material intake per day is about 80tons, It requires about 0.55 hectares, so the land will cost about TZS 120,000,000 (€ 55,773.78) for a package of 0.6 hectares.

It's a good idea to buy the land than renting for this kind of project, because it's a long time investment and its cost a lot of money for the construction of the whole plant, so it's going to be very expensive to break it down and fixing it to the other area. It's possible to sell the same land for higher price if it this project will be crushed down later.

4.2. Construction of the plant

One has to begin with preliminary planning and blueprinting which is small scale fermentation test, involvement of project experts. These are civil engineering technics. Then one has to contact authorities for consulting, these authorities includes, Tanzania Ministry of Industry, Trade & Marketing ,National Environment Management Council (NEMC) , Dar es Salaam water and sewage Authority(Dawasa) .

After the consultancy from the specific authorities, one has to write application to different authorities for permits and licenses. As permission of construction of the plant, allowance according to safety regulations, permission from Dar es Salaam water and sewage Authority(Dawasa) , license from

Tanzania Ministry of Industry, Trade & Marketing , National Environment Management Council (NEMC).

4.3. Operation management

This is cost profit analysis; here one has to determine all basic costs of the whole project from the construction of the plant to operation costs. On search for the companies around which deals with production of electricity from biogas, one managed to find a company which based in German, its name is ZORG BIO GAS AG .Zorg Biogas AG executes full range of engineering services for biogas. Zorg Biogas AG designs, procures, constructs and operates biogas plants. Zorg Biogas AG is a member of German Biogas Association. It has about 50 employees; there are specialists in the Zorg Biogas's team with 30 year experience of biogas plant operation. And they offer their services abroad as well, their services includes, on site consultancy, trouble-shooting, training, shipping the machinery to your destination.

One have decided to consider Zorg Biogas AG as the main constructor of the project, it's very expensive project. It will be more convenient to work with Zorg Biogas AG because they have enough experience in this field and not only handle the construction of the plant but also they offer training to our operators. What are we looking for than that? So Zorg Biogas AG is our constructor.

In the Zorg Biogas AG price list, they are selling the machines according to the inlet capacity of the raw material per day. Because it's just the beginning of the this project it's better to buy the technology which include all machinery of low price at minimum inlet capacity of 80tons per day of raw materials .Consider two table below, one is technical performances and price list.

Table 10: Technical performances of biogas plants on municipal solid waste

Characteristics	Parameters	Values
Raw material capacity (inlet)	tons/day	80
Biogas production	m3/day	16,000
Electrical power consumption	kW	100
Heat power consumption	kW	300
Maintenance personnel	operator	1
Area required	hectares	0,55

Solid bio-fertilizer output	tons/day	48
Liquid bio-fertilizer output	m ³ /day	12

Table 11: Price list for the biogas plant construction

Raw material capacity (inlet), tons/day	Project documentation	Engineering	Equipment(steel elamel coated tanks)	Construction
80	€ 120000	€50,000	€ 1,700,000	€ 1,700,000

After production of biogas in large quantity it transferred to the co-generator, for the final process of generation of electricity from bio gas. The type of co generator to be used at the beginning of the project it's better to buy the one which can consume to the whole bio gas produced per day. By doing so it will minimize the operation time as a results cut down the wages, also it will increase the production of electricity.

As it has been planned the project , at the beginning the plant will be able to produce about 16,000 m³/day of bio gas from the inlet raw materials of about 80tons/day. It its better buy the co generator of which will be able to consumer all most the whole amount of bio gas produced with in a day. For best, co generator below will match with a production of bio gas of about 16,000m³/day

Table 12: Technical performances and price of co generator

Electric power, kW	Heat power, kW	Biogas consumption, Nm³/h	Price, €
1489	1446	603	1,058,000.00

The co generator with technical features above it's the one to buy, because it can be used to produce electricity as much as the bio gas available to the maximum level. As long as this is long term investment, then it's better to buy this type of co generator. This type of co generator will be able to consume about 603Nm³ of bio gas per hour to produce about 1489KW of electricity. Therefore this co generator will consume about 14472 m³ for about 24 hours and be able to produce about 35736KWh. The total working hour of about 24hours for 3 working shift of 8hours each.[29]

4.4. Construction costs of the plant.

1. Project documentation € 120,000
2. Engineering €50,000
3. Equipment € 1,700,000
4. Construction € 1,700,000
5. Co generator (CHP) €1,058,000
6. Land € 55,773.78

Total construction cost is €4,683,773.78

4.5. Estimated operation costs.

Below is the list of estimated operation costs, these are the cost which will be taken during the operation of the plant, some of them will go down to zero, such as heat in which 300kw is minimum amount required by the biogas plant; the co-generator produce heat as by product, so it can be used to run the biogas plant (in this case heat cost needed is 0)

1. Raw materials

The type of raw materials applied in this biogas plant is solid municipal waste, which is available in the central dump of Dar es Salaam. The plant management needs a licence from the regional commissioner of Dar es Salaam for getting access of the raw materials in vingunguti dump, and transferring them from the dump to the plant without exposing them to the environment.

2. Collection and transportation

Collection and transportation of raw materials from different sources in the city will be handled by the company itself. So management of the plant is expected to lease about one truck (10tons truck) from the truck dealers in Dar es Salaam; they always lease trucks for a maximum period of six months else otherwise one has to renew the contract for more time desired. Services and maintenance of the trucks it's upon to them, the biogas plant management has nothing to do than using them, and it costs €100 per day. In a period of six months it will cost the plant management about **€18,000** for leasing one truck.

The plant is located about 22km from the city center, and about 15km from the central dump of Dar es Salaam city (vingunguti dump). Raw materials for the biogas plant are available at vingunguti dump. After getting a licence from regional commissioner of Dar es salaam, it will be possible to take solid waste from vingunguti dump to the plant which is located in vikindu about 15km.

As maximum amount of the raw materials required per day is 80tons per day it means the truck have to go and carry those raw materials from vingunguti dump for about 8 trips per day and will cover 240km per day, this is equivalent to about 48litres of diesel as the fuel consumption rate of Hino trucks is 0.2L/km. This means 240km is 48L of diesel which is equal to **€44** per day.

3. Water supply

The expected amount of water which the plant will consume is not yet known because it is not fixed; it varies with production in reference to the condition of the raw materials used. Currently water is distributed through the Dar es Salaam Water and Sewerage Corporation (Dawasco), the price rate is 0.9TZS/L.

It had been noticed that in biogas plant water is used this rate 9 litres of water per m³ of gas .In this project , the biogas produced is about 1600 meter cubic .

Estimated water to be consumed = the rate of water consumption * expected of biogas produced

$$= 9 \text{ litre/metre cubic} * 1600 \text{ metre cubic}$$

$$= 14400 \text{ litres}$$

Cost of consumed water = water price rate * estimated water consumed

$$= 0.9 \text{ TZS/L} * 14400 \text{ L}$$

$$= 12960 \text{ TZS per day. (€5.84645 per day)}$$

$$= 388800 \text{ TZS per month (€175.417 per month)}$$

4. Electricity

The biogas plant is expected to consume electrical power of approximately 100kw per day which is equal to .This is usually at the beginning of the plant but later on it will use its own electricity generated by co generator(Molten Carbonate Fuel Cells) which produce electricity and heat. The amount of heat power required is about 300kw.The cost of electricity will be charge based on the price rate which is 79TZS per kWh,

Cost for one day= price rate * time * electrical power used.

$$= 79 \text{ TZS/kwh} * 24 \text{ hours} * 100 \text{ kw}$$

= TZS 189600

= €85.4478

5. Capital costs

Usually capital costs consist of redemption and interest for the capital taken up to finance the construction costs. But in this thesis, the main assumption is that” capital is available no need of loan from bank “so the capital cost is 0.

6. Human Resource

Table 13: human resources department

	Number of people	Expected wages/salary per month	Total per month
Mechanical & electrical maintenance and repair technicians	4	€400	€1600
Biogas plant operators	6	€400	€2400
Drivers	1	€300	€300
security guards	6	€250	€1500
cleaners	6	€150	€900

Supervisors	3	€400	€1200
Biogas engineer	1	€1000	€1000
Laboratory technicians	2	€400	€800
Electrical engineer	1	€1000	€1000
Electrical technicians	3	€500	€1500
Total			€12200

4.6. Electricity prices in the local market

TANESCO, Tanzania electric supply company is the main supplier of the electric in the whole country. TANESCO is the only customer of our product which is electricity. According to the interview with one of the staff from TANESCO in Dar es Salaam, he said they buy electricity from two independent power producers.

The first one generate electricity from natural gas which is SONGAS (songo songo gas) and the other one generate electricity from diesel oil which is Independent Power Tanzania Ltd (IPTL). In the interview he mentioned the range of prices which they buy electricity from these independent power producers which is approximately TZS 65 per kWh (0.0299793 EUR per kWh) to TZS 70 per kWh (0.0320509 EUR per kWh).

5. RESULTS

5.1. Profitability

In the profit analysis of the this project, let's consider the first month, And ignore some other the operation costs which their values was not able to be found until the plant start running, but they are very small compared to the others, so they cannot have a big effect on the results.

Operation cost for the first month;

Salary and wages; €12200

Electrical energy; $€85.4478 \times 30 = €2563.434$

Fuel; $€44 \times 30 = €1320$

Leased truck; €3000

Total monthly operation cost= **€ 19083.434** (assumption other miner costs are ignored)

Sales;

From the technical description of the co-generator (Molten Carbonate Fuel Cells) ,it's capable of consuming about 14472 m3 of biogas produced per day from 80tons of raw materials for about 13.26 hours and be able to produce about 35736KWh of electricity. Total working hour of about 24hours, three working shift of 8hours each.

One will sell electricity to Tanesco at cheapest price compared to other independent power producers, which will be TZS 65 per kWh (0.0299793 EUR per kWh).

Total sells per day= power produced per day * power price

$$= 35736 \text{KWh} \times 0.0299793 \text{ EUR per kWh}$$

$$= 1071.34 \text{ per day}$$

Total sells per month = €1071.34 per day *30 days

$$= € 32140. 20$$

Gross profit;

Gross profit = Total sells per month - Total monthly operation cost

$$= € 32140.20 - € 19083.434$$

$$= € 13056.766$$

5.2. Payback period

Payback period = $\frac{\text{Cost of project}}{\text{Annual cash in flow}}$

Estimated annual cash inflow = monthly gross profit * 12 months (assumption other miner costs are ignored)

$$= € 13056.766 * 12$$

$$= € 156681.192$$

Then;

$$\text{Payback period} = €4,683,773.78 / € 156681.192 = 29.89$$

Payback period is 29.9 years .it takes 29 years for the investors to get their month back.

6. CONCLUTION

From the research made in literature review it was found that “it is possible to run this project in Tanzania”. The research was made under consideration of level of technology in Tanzania, the economy of Tanzania, market, rules and regulation and finally security which is the most important before considering investing anywhere especially in the third world countries.

From the result, the economic viability of the project it's positive. The project will make a gross profit of about € 13056.766 per month and the annual cash inflow is €156681.192 and the Payback period is 29.9 years .It will takes 29 years and 10 months for the investors to get their money back. It's a long term investment. Some of the expenses have to be cutted off to increase the profit and decrease the payback period , such leasing trucks is unnecessary .One have to buy to cut the cost as long as the project runs up to 30 years .

Also the profit can be increased by the additional of another co-generator (CHP)to produce more electrical power and rise annual cash inflow hence reduce the payback period. No need of expanding the plant it cost more for doing so.

7. RECOMMANDATION

This recommendation is not only for running this project in Tanzania. This project is the great deal for third world countries especially in Africa where we have hard time in availability of Electric energy. During the quick research on some people from Africa most of them had been complaining about unstable availability of the electrical power, also some of the European citizen who had been living in Africa they have the same complain concerning the electrical power.

As long as , there is possibility of getting enough funds for running a green renewable power production , that is good opportunity to help people and make a big profit out of it, because the market is stable ,electrical power price it had never went down , it always rise and it's risk free. This is among the best investment opportunities in African countries.

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